COMPARISON OF SCATTERING AMPLITUDES FROM VARIOUS TRANSDUCERS USING DIFFRACTION AND ATTENUATION CORRECTIONS

S. J. Wormley and D. O. Thompson

Ames Laboratory, USDOE
Iowa State University
Ames, IA 50011

INTRODUCTION

As a part of a project to develop an ultrasonic multiviewing transducer which is capable of providing sufficient information for flaw reconstruction, results have been obtained that address certain phases of the required signal processing routine. It is well known that individual ultrasonic transducers show a considerable variation in signal responses. Inasmuch as the multiviewing transducer uses a sparse array of individual transducers arranged in a particular geometry, it becomes important that signal processing routines be developed and applied which overcome these variabilities. There are, of course, several possible sources of variability in transducer performance. These include those of measurement (diffraction, attenuation and effects associated with imperfect deconvolution processes), and those due to fabrication (transducer design, materials, reproducibility of fabrication techniques, etc.). The results presented in this paper address only the former of these two. In particular, they represent a limited experimental assessment of the adequacy of specific data processing procedures for three different transducers and three different samples utilizing Weiner filter concepts and diffraction and attenuation corrections. Use is made of theoretical curves for scattering amplitude as an absolute standard of comparison and therefore as the criterion of adequacy.

II. EXPERIMENTAL PROCEDURES

A. Samples

In order to provide a reasonably rigid assessment of the signal processing procedure mentioned above, three sample configurations were selected that provided a broad range of both flaw scattering characteristics and material properties associated with ultrasonic propagation. A summary of the samples utilized is given in Table I.

Table I.

Host Material	Flaw
Lucite	114 micron tin-lead sphere
Titanium	200 x 400 micron oblate spheroidal void
Glass	140 micron spherical void

Since these samples have been used in other investigations, details regarding their preparation are not reproduced here but may be found in appropriate references (1,2,3).

B. TRANSDUCERS

Three transducers selected from a "matched" set of eight were used in this work. They were manufactured by Panametrics and were nominally 1/4" in diameter with a center frequency of 15 MHz, and are identified by serial number in the figures of this paper.

Various studies were performed to quantify the transducer response characteristics. Figure 1 shows the on-axis pressure profiles that were obtained for the three transducers using tone-burst excitation from a Matec generator at 15 MHz in a water bath. Although the null points in the near field are located at approximately the same distances from the transducer face, there is as much as a factor of 3 variability in the transducer amplitude responses. The ordinate in this figure is relative and is given in units of volts; it reflects the gain of the detector used which was the same for all transducers in this experiment. Detailed values of the positions of the last null were used to obtain the "effective" transducer diameter for use in later calculations. As noted above, the serial numbers given refer to the specific transducer.

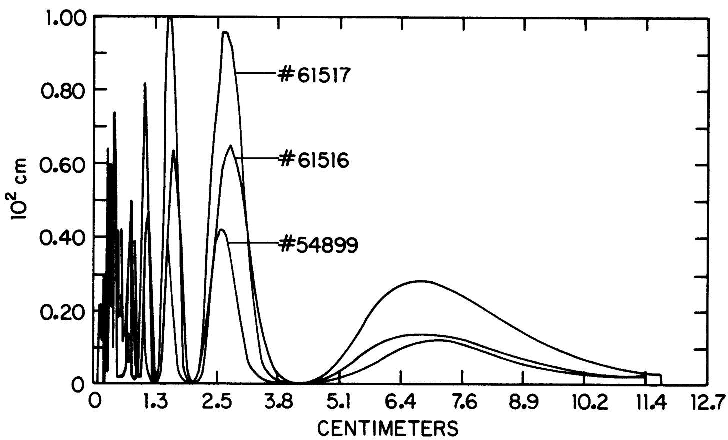

Fig. 1. On axis pressure profiles at 15.0 MHz for 3 transducers.

In Fig. 2 are shown the spectral distributions for the three transducers obtained from back surface reflections from the three different sample materials. In this case the transducers were driven in pulse excitation using a Panametrics pulser. The data shown reflect primarily the significant differences in attenuation associated with the three sample materials.

III. EXPERIMENTAL PROCEDURE AND RESULTS

Using the samples and transducers described in the previous section, a systematic series of ultrasonic scattering measurements were made. In this series, each transducer was used to measure the backscatter from each of the flaws thus providing a set of nine curves for comparison. These measurements were all made in the pulsed mode at normal incidence and with a separation of about 6 cm in water between the transducer and the sample face. According to the results shown in Fig. 1, this is sufficient separation to ensure that far field conditions were obtained. The Panametrics pulser settings used in this series were the same as those used in obtaining the results shown in Fig. 2.

In Fig. 3 are shown the experimental results obtained in this series. Each plot in this figure gives the Fourier transform of the backscattered time domain pulse for the three transducers

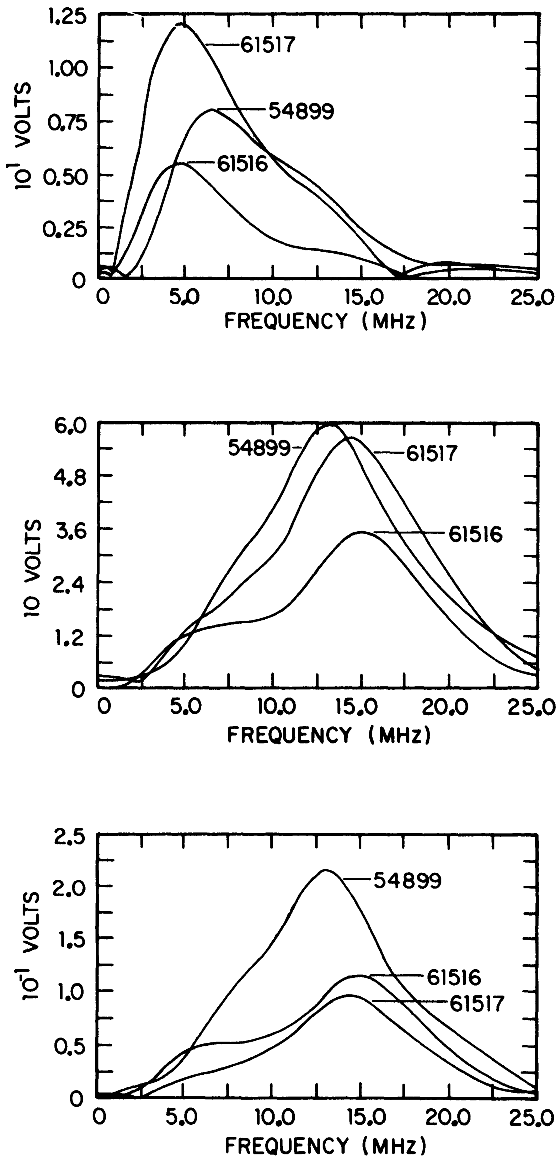

Fig. 2. Spectral response from back surface of three host materials for three transducers.

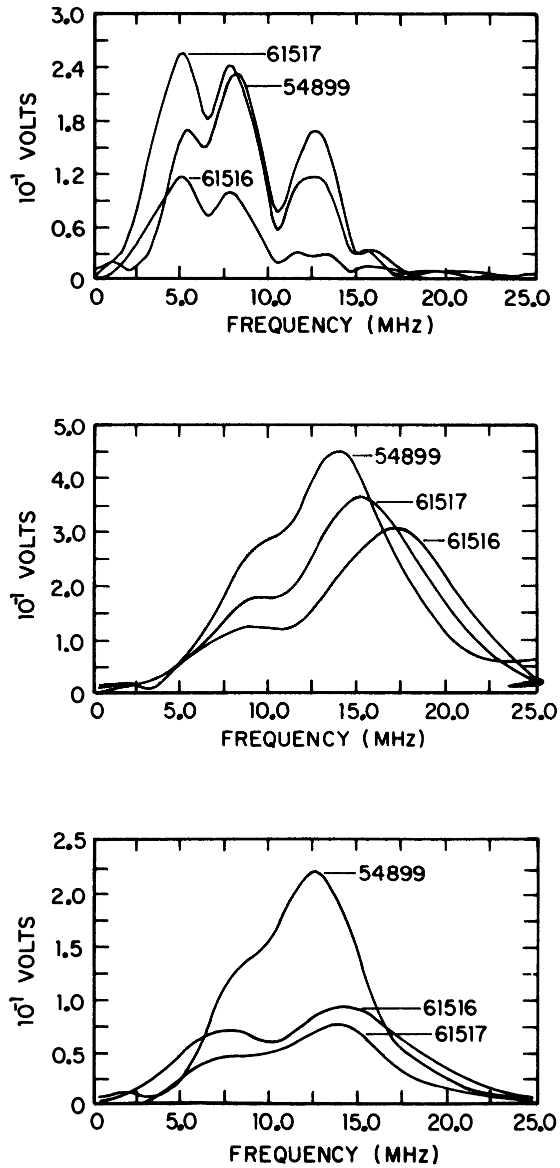

Fig. 3. Spectral response from flaw for three transducers and three host materials.

and one of the samples. As noted, the top figure gives the results for the tin-lead inclusion in Lucite, the second provides the same kind of information for the oblate spheroid void in titanium, and the third provides backscatter results for the spherical void in glass. It is to be noted that values on the ordinate in these plots reflect the gain settings used in the ultrasonic transmission and detection system, and are given in relative units of volts. The gain settings used for the acquisition of these data were the same as those used to acquire the data of Fig. 2.

Two signal processing procedures were then applied simultaneously to the results of Fig. 3. One of these is deconvolution in which the results of Fig. 3 were deconvolved with those given in Fig. 2 using the Weiner filter technique as described by Richardson and others (4,5). The other processing correction utilized is the measurement model correction recently described by Thompson and Gray (6,7). This is an analytic model that provides a convenient way to account for attenuative and diffraction effects. The "noise" term was assumed to be independent in frequency and was taken to be 10 percent of the maximum value of the respective curves given in Fig. 2.

The results of application of these processing steps to the data of Fig. 3 are given in Fig. 4. This figure retains the same sample order used in Fig. 3. There are, however, some significant differences that should be emphasized. First, it should be noted that the ordinate in each of the plots is now a flaw scattering amplitude and is given in absolute units of cm. This is an important result which relates directly to the physical scattering properties and in which the dependence upon apparatus settings has been removed. Secondly, the results obtained for each of the transducers and each of the samples can be compared to theoretical scattering results. The dotted curves given in each of the plots is a theoretical reference which can be used as the "standard" for comparison of results. From top to bottom, the theoretical scattering curves are due to references. Finally, even though it is evident that the dual processing treatment has reduced the transducer variability to a considerable extent, it is also evident that the processing has not produced an universal response that is characteristic of the scatterer only. This would be the expected result if the processing were adequate in all respects.

An additional series of measurements was made using a single transducer and sample for the purpose of obtaining an independent estimate of the reproducibility of any one curve one such as those shown in Fig. 4. Transducer 61516 was used in this series together with the titanium sample. In Fig. 5 are shown the results of these experiments. The results show that reproducibility errors produce a spread in the data of not more than ±6 percent.

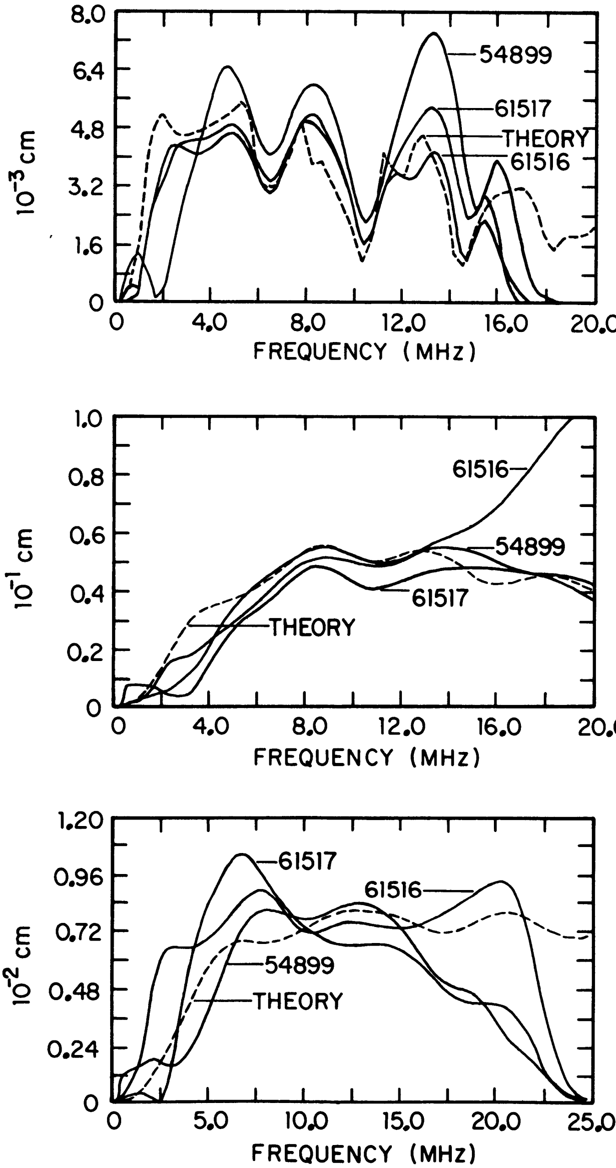

Fig. 4. Corrected scattering amplitude from three samples and three transducers.

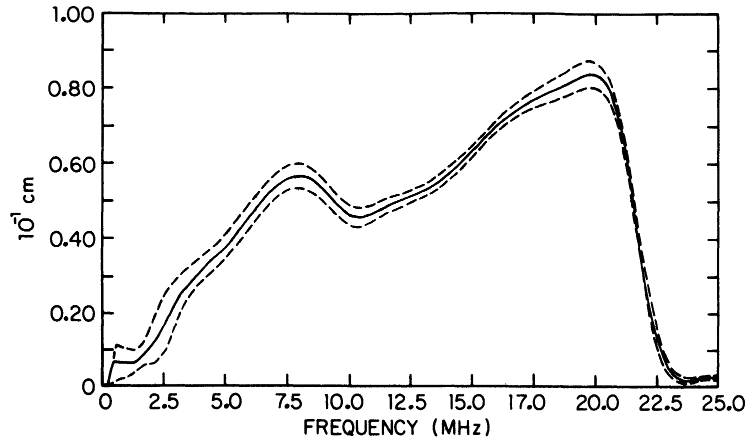

Fig. 5. Corrected scattering amplitude for transducer 61516 with titanium showing mean ± 1 standard deviation for 9 independent experiments.

IV. CONCLUSIONS

Although the present results are limited to a rather small number of transducers and samples, they suggest that certain conclusions may be drawn and areas for additional research. These are summarized below.

a. The dual processing steps used (deconvolution with a Wiener filter and diffraction/attenuation correction) appear to be sufficient to eliminate transducer variability in the center regions of the scattering amplitude curves where the signal/noise ratios are reasonably large (8-10) and away from both the low and high frequency ends of the spectrum. In the center region there appears to be no greater spread in results obtained than would be expected from reproducibility errors. This is not true at the ends of the spectra.

b. It is suspected that the deviations that remain in the scattering amplitude curves at the ends of the spectrum are due to inadequacies and difficulties inherently associated with the deconvolution process and not with the corrections for attenuation and deconvolution. In particular, it is clear that the treatment of "noise" in the deconvolution used is both inadequate and incorrect. As noted earlier, the noise term was chosen to be 10 percent of the maximum response; qualitative studies were performed but not reported herein in which this choice was varied from about 3 to 15 percent. These variations did not appreciably alter the center portions of the response curves, but significantly altered the ends of the spectrum - particularly the high end - where low signal/noise ratios are in evidence. Future research efforts need to be directed to work in which correct noise terms are used and to the examination and evaluation of other data processing procedures which may bypass some of the inherent difficulties associated with deconvolution.

c. The theoretical scattering amplitude curves (8,9) form an important element of this work in that they provide comparison "standards" for the experimental results that are completely independent of all measurement procedures and transducer variables. As pointed out in earlier work, such curves should be of value in the development of ultrasonic standards and calibration techniques.

V. ACKNOWLEDGEMENTS

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